NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A METHODOLOGY FOR EVALUATING A JOINT MOBILIZATION PLAN USING THE JOINT THEATER LEVEL SIMULATION (JTLS)

by

Mark J. Sullivan

September 1996

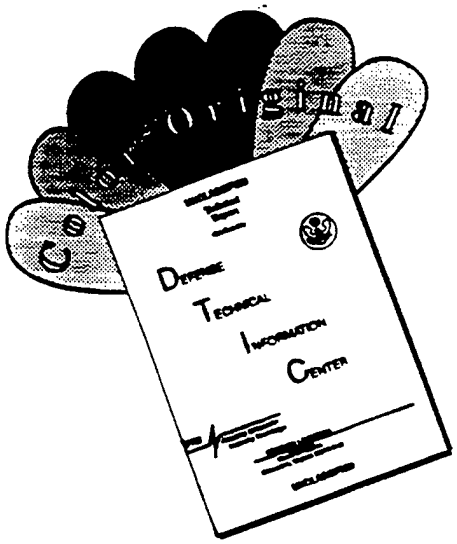
Thesis Advisor: Sam Parry

Approved for public release; distribution is unlimited.

19970212 150

DTIC QUALITY INSPECTED 3

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1996	Master's Thesis

4. TITLE AND SUBTITLE
A METHODOLOGY FOR EVALUATING A JOINT MOBILIZATION PLAN USING THE JOINT THEATER LEVEL SIMULATION (JTLS)

5. FUNDING NUMBERS

6. AUTHOR(S)
Sullivan, Mark J.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Joint Warfighting Center
Fort Monroe, VA 23651-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

One of the primary training tools available to a Joint Commander in Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. Computer Aided Exercises (CAXs) are an essential part of training a component staff, however one weakness lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise, and not only is no quantitative data captured but in most cases they don't receive a detailed debrief. This research presents a methodology for evaluating the performance of joint mobilization tasks as set forth in the Universal Joint Task List (UJTL). The UJTL provides both the staff and evaluators with a common document outlining the critical events and activities which require successful accomplishment. The UJTL is organized in such a manner which defines activities such as logistics, intelligence, and force protection.

It is the purpose of this thesis to provide a methodology for objectively assessing the effectiveness of a staff's joint mobilization plan. Experimental runs using the Joint Theater Level Simulation (JTLS) are presented to demonstrate the methodology and the subsequent analysis process.

14. SUBJECT TERMS Mobilization, Computer Aided Exercise, JTLS			15. NUMBER OF PAGES 73
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

DTIC QUALITY INSPECTED 3

Approved for public release; distribution is unlimited

A METHODOLOGY FOR EVALUATING A JOINT MOBILIZATION PLAN USING THE JOINT THEATER LEVEL SIMULATION (JTLS)

Mark James Sullivan
Lieutenant, United States Navy
BS, Northeastern University, 1988

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1996

Author: _____
Mark James Sullivan

Approved by: _____
Sam Parry, Thesis Advisor

_____
Greg Brouillette, Second Reader

_____
Frank C. Petho, Chairman
Department of Operations Research

ABSTRACT

One of the primary training tools available to a Joint Commander-in-Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. Computer Aided Exercises (CAXs) are an essential part of training a component staff; however, one weakness lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise and not only is no quantitative data captured, but in most cases they don't receive a detailed debrief. This research presents a methodology for evaluating the performance of joint mobilization tasks as set forth in the Universal Joint Task List (UJTL). The UJTL provides both the staff and evaluators with a common document outlining the critical events and activities which require successful accomplishment. The UJTL is organized in such a manner which defines activities such as logistics, intelligence, and force protection.

It is the purpose of this thesis to provide a methodology for objectively assessing the effectiveness of a staff's joint mobilization plan. Experimental runs using the Joint Theater Level Simulation (JTLS) are presented to demonstrate the methodology and the subsequent analysis process.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

One of the primary training tools available to the Commander-in-Chief (CINC) for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. This is commonly referred to as a Computer Aided Exercise (CAX). The main objective of a CAX is to create an environment where the staff can implement plans, update those plans as required, and make decisions based upon stochastic results. One weakness of the CAX lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise, and not only is no quantitative data captured but in most cases they don't receive a detailed debrief. Evaluating the performance of the players is important because it provides feedback as to how effective the training plan is and it identifies mission essential in need of training.

The objective of this thesis is to develop an after action reporting process (AARP) for representing CINC staff performance in the execution of joint tasks during the conduct CAX. For this thesis, the CAX will be conducted using the Joint Theater Level Simulation (JTLS), focusing on Strategic National Tasks One, Six and Seven which all deal with strategic deployment of forces into a theater. Specific objectives are:

A. Develop Measures of Effectiveness (MOEs) that summarize mobilization planning and execution conducted during a CAX. CINCs are tasked with developing OPLANS and supporting Mobilization plans. Included within a mobilization plan is Time Phase Force Deployment Data (TPFDD). A TPFDD lists assigned, augmented, and

supporting forces scheduled to arrive into a theater along with each unit's required arrival date. Individual force requirements are usually expressed in battalion sized units. This Thesis will attempt to show how a specific TPFDD influenced the outcome of the war. How does the particular mix of forces compare to the enemy's mix of forces in theater at any given time ? This will be done by examining specific sets of friendly and enemy units on hand at particular critical times during the CAX and develop measures to compare them (For example: Was the outcome of the war affected because several ships carrying troops were sunk by enemy submarines and never arrived in theater ?)

B. Evaluate the MOEs with data collected from an actual CAX

C. Develop the AARP based on graphical presentation of the MOEs gathered during a CAX.

The methodology is not intended to assess execution of joint tasks. Its focus is on evaluating process performance that ultimately is used to provide insight into significant events observed during the CAX. Implementation of the methodology presented places no additional burden on the players, because no special player interaction is required. The entire methodology can be implemented using only a commercial spreadsheet package and thus is conducive to production of a quick analysis capable of being presented to the players before the disperse at the end of the exercise.

I. INTRODUCTION

A. BACKGROUND

The Chairman Joint Chiefs of Staff (CJCS) Memorandum of Policy 26 (MOP 26) establishes a program for carrying out the joint training responsibilities of the CJCS, the Unified Commanders-in-Chief (CINCs), and the CINC's component staffs. MOP 26 institutes a method for identifying training requirements through the review of the CINC's mission and the compilation of the Joint Mission Essential Task List (JMETL). A CINC's JMETL is intended to provide the basis for all joint training.

The Universal Joint Task List (MCM 147-93), a supplement to the Joint Training Manual (MCM 71-92), is a comprehensive listing of all joint tasks pertaining to the Armed Forces of the United States. It is intended to provide a common language for describing joint warfighting capabilities throughout the entire range of military operations to include operations other than war. Specifically, tasks are defined as they relate to the strategic (both national and theater), operational, and tactical levels of war. Each joint task is broken down into supporting tasks which may in turn be further refined into enabling tasks.

One of the primary training tools available to a CINC for training his staff on their joint mission essential tasks is a command post exercise supported by a computer simulation model. This is commonly referred to as a Computer Aided Exercise (CAX). The primary role of the computer simulation is to present a decision environment within

which the staff can be presented with realistic, stochastic results. Based upon this simulated environment, staffs implement plans, monitor the current situation, and further develop or alter their plans as dictated by changing requirements. CAXs are an essential part of training a component staff; however, one weakness of these valuable training tools lies in the measurement of the level of training received by the players. In most CAXs the players rapidly disperse after the exercise and little quantitative data are captured during the running of the exercise that will allow for quick post exercise analysis. Measurement of a staff's capability to perform mission essential tasks is ultimately important for two reasons. First, it is important to insure that training resources are being used wisely and progress is being realized in the training program. Second, it is important to determine the tasks for which there exists the greatest need for further training. [Ref. 1]

B. PROBLEM STATEMENT

The objective of this thesis is to develop an exercise analysis methodology for evaluating CINC staff performance in the execution of joint tasks during the conduct of a CAX, focusing on Strategic National Tasks One, Six, Seven which deal with strategic deployment and redeployment of forces into and out of a theater. Specific objectives are as follows.

1) Develop Measures of Effectiveness (MOEs) that summarize mobilization planning and execution conducted during a CAX. CINCs are

tasked with developing OPLANS and supporting Mobilization plans, which include a Time Phase Force Deployment Data (TPFDD). A TPFDD lists assigned, augmented and supporting forces scheduled to arrive into a theater along with each unit's required arrival date. Individual force requirements are usually expressed in battalion sized units. This thesis shows how execution of a specific TPFDD influenced the outcome of the war. This was done by examining, over time, the relative distances between the strength weighted centers of mass of the two opposing forces. For example, was the outcome of the war affected because several ships carrying troops were sunk by enemy submarines and never arrived in theater?

2) Test the methodology using the Joint Theater Level Simulation (JTLS). Develop and demonstrate a potential post-exercise analysis. This objective entails a practical application of the methodology presented here to an existing theater level simulation. Included in this are the alignment of the model's database with required parameters necessary for utilizing the methodology, development of algorithms required in post processing and specification of output format.

This research parallels similar efforts by Capt Kerry Gordon, USMC [Ref. 2], on Universal Joint Tasks involving firepower; LT John Mustin, USN, [Ref. 3] involving force protection of Naval units; CPT Kevin Brown, USA, [Ref. 4] on tasks involving

mobility of maneuver units; CPT John Thurman, USA, [Ref. 5] on tasks involving force protection; and Maj. Mark Cwick, USMC, [Ref. 6] on tasks involving amphibious operations. It is recommended that these additional theses be read in conjunction with this document, since the performance of one joint task during a CAX often impacts the performance of another joint task. The interested reader is also referred to the Naval Postgraduate School Technical Report entitled *Evaluation of Functional Area Performance in Internal Look 96,* for a practical application of these methodologies in analyzing a Central Command exercise.

C. THESIS STRUCTURE

Chapter II provides a brief overview of the mobilization planning process. Chapter III describes the proposed analysis methodology used to assess staff performance. The presented methodology focuses on the analysis of significant events that occur during an exercise. Chapter IV applies the methodology to a typical exercise scenario using JTLS. This chapter discusses the data manipulation necessary for post exercise analysis using an existing computer simulation. Chapter V summarizes the methodology and provides recommendations for further refinements and analysis.

II. JOINT TRAINING PROCESS

"Train and exercise today's forces on today's equipment with today's doctrine ..."
General Shalikashvili, CJCS

The nature of modern warfare demands that we fight as a team. Joint force Commanders choose the capabilities they need from the air, land, sea, space, and special operations forces at their disposal. [Ref. 7] In order to fight successfully the resulting joint team needs to train as an integrated force. Critical to ensuring effectiveness is recognition that the military is a "hands-on profession." Leaders at all levels do most of their learning during training, thus making "realistic, demanding, and objectively measured training and exercises a must." [Ref. 7]

A. DEVELOPMENT OF THE UNIVERSAL JOINT TASK LIST (UJTL)

The latest version of the UJTL was developed by Dynamics Research Corporation (DRC) under the direction of the Joint Exercise and Training Division (JETD) of the J-7 Directorate, the Joint Staff. The project was a two year effort which leveraged Army lessons learned on similar activities. Over 120 organizations provided design input, all of which were coordinated through the Joint Staff, CINCs, Services, and other concerned agencies. The UJTL provides a common language for describing joint warfighting capabilities in terms of tasks, conditions and standards. Furthermore, capabilities within it

describe the entire range of military operations, to include operations other than war. [Ref. 1]

The UJTL is divided into four levels of war as follows:

- Strategic National (SN) - The level of war at which a nation determines national or multinational security objectives and develops and uses national resources to accomplish these objectives.
- Strategic Theater (ST) - Similar to Strategic National except assets are allocated to achieve theater specific objectives.
- Operational (OP) - The level of war at which campaigns and major operations are planned, conducted and sustained to accomplish strategic objectives within theaters of operation.
- Tactical (TA) - The level at which battles and engagements are planned and executed involving units at a tactical level.

The UJTL contains the joint task list, joint conditions list and associated task measures. Figure 1 describes the joint task list which consists of all joint, supporting and enabling tasks at each of the three levels of war. The joint conditions list contains various physical, political, social and military states that describe operational environments. Descriptive measures are parameters describing task performance that, when specified in terms of conditions and a minimum acceptable level of performance, are a statement of the task's standard. The joint measures list provides performance criteria at the task level to assist commanders in assessing staff performance and determining those tasks in greatest need of additional training. [Ref. 8]

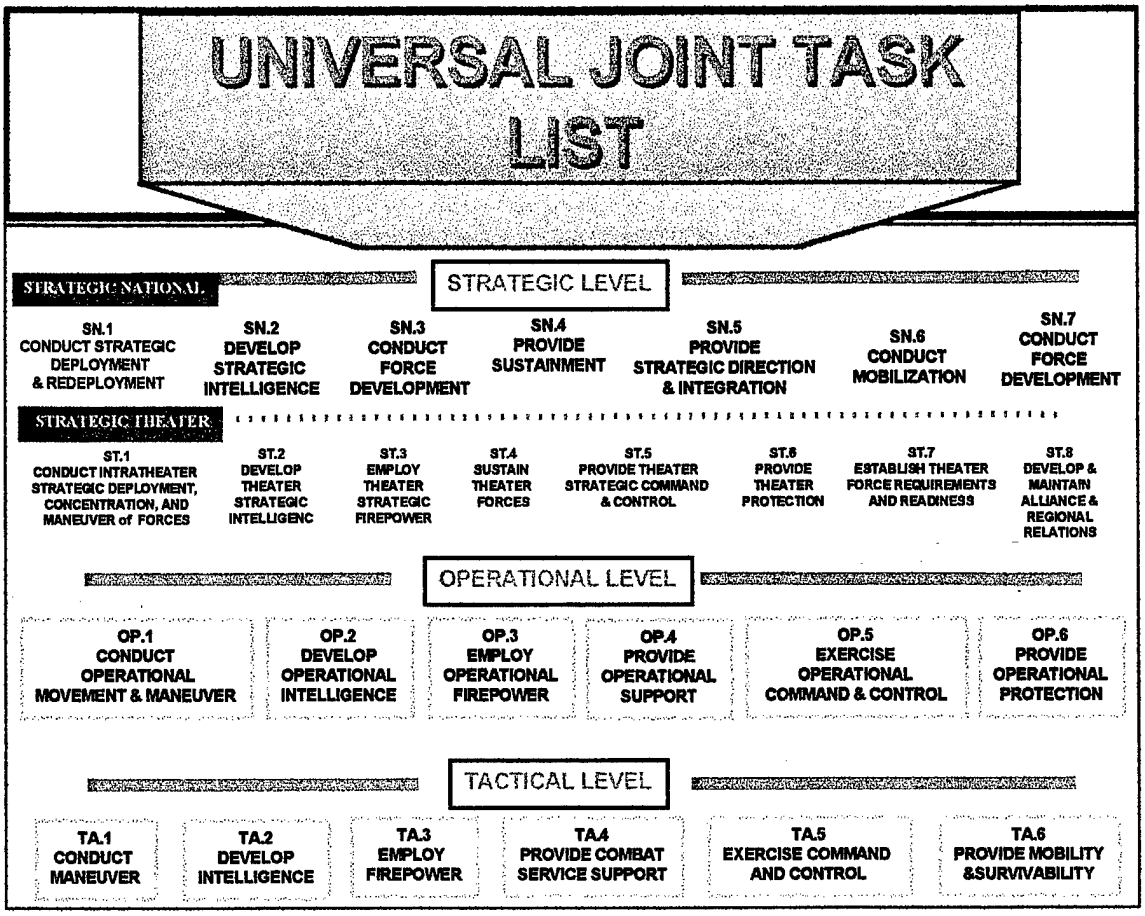


Figure 1. Universal Joint Task List Diagram

B. JOINT MISSION ESSENTIAL TASK LIST (JMETL)

Joint Mission Essential Tasks (JMET) are selected from among the tasks found in the UJTL. Tasks that are identified as essential to the accomplishment of the combatant commander's mission are compiled in the Joint Mission Essential Tasks List (JMETL). A CINC's JMETL is intended to provide the basis for all joint training.

C. JOINT TRAINING PROGRAM

> The art of war owns certain elements and fixed principles . We must acquire that theory, and lodge it in our heads– otherwise we will never get very far. *Frederick the Great* [Ref. 9]

The joint training program provides guidance for all joint training within the DOD. Required national capabilities are specified in the Joint Strategic Capabilities Plan (JSCP) as determined through analysis of international obligations and Operations Plans (OPLANS). The JSCP provides the strategic direction required to coordinate the deliberate planning efforts of the combatant commanders in pursuit of national strategic objectives and to integrate their efforts with those of the remainder of the Joint Planning and Execution Community (JPEC). The JSCP is the link between strategic planning and joint operation planning. It is the primary vehicle through which the Chairman of the Joint Chiefs of Staff exercises his responsibility to provide for the preparation of operation plans. The JSCP initiates deliberate planning by assigning planning tasks to the combatant commanders, apportioning major combat forces and resources, and issuing planning guidance to integrate the joint operation planning activities of the entire JPEC within a coherent focused framework.

Essential capabilities are reflected in the CINC's Joint Mission Essential Task List which identifies his priorities and provides the collective requirements base for all joint training. Along with the JMETL, applicable Joint Doctrine and Joint Tactics, Techniques and Procedures (JTTP) are used to develop a CINC's training plan. The overall effect of

the joint training program is to effectively link joint training and joint doctrine to create an efficient joint fighting force.

D. JOINT MOBILIZATION PLANNING

> The Greeks by their laws, and the Romans by the spirit of their people, took care to put into the hands of their rulers no such engine of oppression as a standing army. Their system was to make every man a soldier, and oblige him to the standard of his country whenever that was reared. This made them invincible; and the same remedy will make us so. *Thomas Jefferson* [Ref. 9]

Mobilization planning is heavily influenced by the JSCP which tasks the combatant commanders and their Service components to develop OPLANS and supporting mobilization plans. JSCP provides guidance, assigns tasks, apportions major combat forces and specifies items of material and lift assets available for planning. Procedures for deliberate planning are designed to assist the JPEC in the timely, efficient development of OPLANS and to provide a consistent framework for the planning process. The deliberate planning process consists of five phases.

1. Phase I - Initiation

During this phase the groundwork is laid for the planning process. Planning tasks are assigned and available resources are identified. The CJCS tasks CINCs to develop operation plans and concept summaries which are usually incorporated into the unit's next JSCP. CINCs are given wide latitude to make whatever plans are necessary to accomplish the assigned task. The assigned CINC is encouraged to consult with the Joint Center for

Lessons Learned (JCLL) as well as the Joint Universal Lessons Learned System (JULLS) to obtain specific practical lessons learned from similar mobilization plans. [Ref. 10]

2. Phase II - Concept Development

During this phase the JSCP tasking is analyzed and factors that possibly could affect mission accomplishment are identified and addressed in the CINCs mission statement. The CINCs mission statement is issued to subordinate and supporting commanders and contains such things as characteristics of the area of operations, enemy capabilities, special weapons, political and psychological considerations and a tentative planning schedule. The CINCs staff, together with subordinate and supporting commanders, then develops Courses Of Action (COA), which are eventually smoothed into the CINCs concept which, after submission to and approved by CJCS, becomes the concept of operations for the plan. The CINCs concept forms the cornerstone for what later becomes the Operations Plan in Concept Form (CONPLAN). [Ref. 10]

3. Phase III - Plan Development

The plan development phase is the phase where the forces are selected and time-phased, support requirements computed, strategic deployments are simulated and analyzed, and shortfalls are identified. The entire process is summarized in Table 1.

STEP 1 FORCE PLANNING
STEP 2 SUPPORT PLANNING
STEP 3 NUCLEAR PLANNING
STEP 4 TRANSPORTATION PLANNING
STEP 5 SHORTFALL IDENTIFICATION
STEP 6 TRANSPORTATION FEASIBILITY ANALYSIS
STEP 7 TPFDD REFINEMENT
STEP 8 DOCUMENTATION
* STEPS LISTED ABOVE ARE NOT NECESSARILY SEQUENTIAL AND MAY OCCUR SIMULTANEOUSLY

Table 1. Plan Development Phase

Major combat forces apportioned to the CINC are designated in the JSCP and are used in this phase to time phase their force lists to sequence the arrival of forces into a theater in accordance with a visualized concept of operations. TPFDD force data include assigned, augmented and supporting forces to be deployed to the area of operations along with forces already on station in the area of operations. Individual force requirements will be expressed at the highest practicable unit level. For instance, a battalion-size unit consisting of a headquarters and subordinate units is shown as a single unit as long as they are moving from the same Port of Embarkation (POE) to the same Port of Debarkation (POD) within a narrow timeframe (3–5 days) . [Ref. 10] Typical force divisions are listed in Table 2.

1. ARMY. Division, Separate Brigade, Armored Cavalry Regiment.

2. AIR FORCE. Combat Squadrons, including their sortie and sortie generation support.

3. NAVY. Carrier Battle Group, Surface Action Group, Amphibious Ready Group.

4. MARINE CORPS. Marine Expeditionary Force, Marine Expeditionary Brigade, Separate Marine Expeditionary Units, Air Contingency Units.

5. SPECIAL OPERATIONS FORCES. Army, Navy, and Air Force Special operations forces and their organic support units.

Table 2. Definitions of Forces

4. Phase IV - Plan Review

In this phase, all elements of the OPLAN and CONPLAN are reviewed and approved by the CJCS. The CINC revises the plan in accordance with any comments made by the CJCS.

5. Phase V - Supporting Plans

In the final phase all required supporting plans are completed and validated. Any changes to the TPFDD can only be made with Joint Staff approval during this phase.

A methodology for assisting the commander and his staff in evaluating the effectiveness of a mobilization plan during a CAX is described in the next chapter. A demonstration of the application of these methods is presented in Chapter IV.

III. MOE DEVELOPMENT

This chapter presents a methodology for developing quantifiable measures of effectiveness for assessing mobilization functions described in terms of the appropriate Universal Joint Tasks. Fundamental to the methodology is the assumption that execution of any given task at a specific level of war is related to the execution of similar tasks at other levels of war. Tasks at different levels can be related to each other by means of a common functionality. Out of this functional relationship comes the concept of horizontal and vertical linkages existing among tasks. A horizontal linkage is defined in the context of a military operation. That is, when conducting a military operation, different tasks (processing movement requirements, movement to Port of Embarkation (POE), movement to Port of Debarkation (POD), movements within Theater) have to be performed in careful coordination with one another to achieve the desired effects. The coordination among such tasks may be in terms of timing, space or degree.

One way of describing these horizontal linkages is through operations templates which are described later in this chapter. An example of a horizontal linkage between tasks is the relationship between UJTL Strategic National task "Conduct Mobilization" (SN 6) and UJTL Strategic National task "Establish Theater force requirements and readiness" (SN 7). The basis for linking these tasks is that the accomplishment of both tasks must be synchronized in time, space, and degree based on the commander's concept of operations in accordance with joint doctrine.

Vertical linkages provide the connecting structure among tasks in the UJTL

across strategic, operational, and tactical levels of war. Although the generic elements of strategic, operational, and tactical mobilization planning are similar, the tasks and subtasks associated with each are distinct in terms of aim, scope and what organization is assigned to perform them. At the strategic level mobilization plans are developed which assemble and organize national resources to support national objectives in time of war or other emergencies. This task includes activating all or part of the reserve components (RC), as well as organizing supplies and materiel. This thesis concentrates on evaluating both the planning and execution of mobilization plans by Joint Warfare Commanders at a strategic level.

Specific steps of the methodology include developing operations templates, relating issues to performance requirements (dendritic) and determining measures of performance and effectiveness.

A. OPERATIONS TEMPLATES

An operations template provides a graphical depiction of the activities performed as part of a military operation. It depicts activities and interrelationships among those activities. The activities represented in an operations template vary from tasks performed by the joint warfare commander and staff to subordinate commanders. Operations templates represent various interactions and interdependencies among tasks that influence their combined effect on mission success. Templates are especially useful in understanding the performance relationships among tasks in the context of the commander's concept of

operations. Operations templates aid the joint force commander in identifying the most essential warfighting tasks and incorporating them into the training plan in advance of actually conducting such military operations.

Operation templates depict two types of interrelationships among tasks. One type is temporal relationships in which either one task has to be completed before another can be started, one task might begin at the same time as another, or a task may have to be repeated periodically. A second type is spatial relationships in which either a task is required to begin or end at a specific location, be accomplished in a place relative to where another task is being performed (e.g., conduct close air support near a maneuvering friendly force) or perform a task at multiple locations (e.g., deploy various ships in a fleet at different locations). Operations templates for mobilization planning and mobilization execution are shown in Figure 2. [Ref. 8]

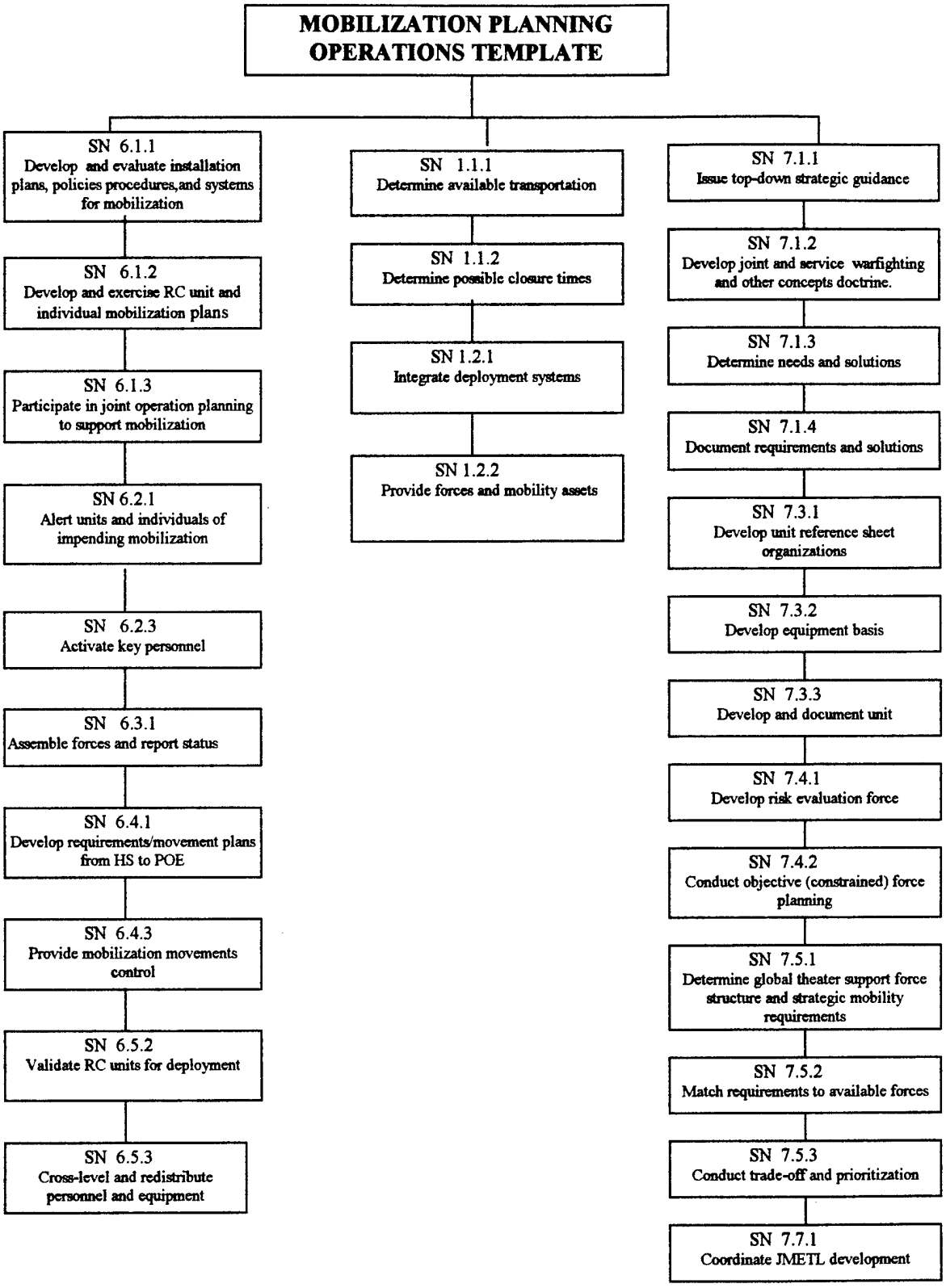


Figure 2. Mobilization Planning Operations Template

B. SIGNIFICANT EVENTS

A major hurdle in developing post exercise analysis methodologies for mobilization planning by a Joint staff is the concept of a significant event. Significant events are classified not only according to significance but also in terms of strategic, operational, and tactical considerations. An example of a strategic significant event would be an Iraqi invasion of Kuwait or a Blue force counter-offensive. An example of an operational significant event would be the joining of a mechanized infantry battalion with its equipment shortly after entering the theater. An example of a tactical significant event would be an infantry platoon engaging an Iraqi force. The analysis in this thesis is primarily concerned with the relative location of friendly and enemy forces; therefore, an example of a significant event would be a change in a Red or Blue unit location or strength. In each of these cases the degree of significance has to be determined based on its contribution to the overall success or failure of a specific strategic, operational or tactical mission.

C. METHODOLOGY

A problem with measuring a joint staff's performance based solely on the outcome of significant events is that it involves the assumption that units arrive exactly according to the TPFDD. Unfortunately, due to the stochastic nature of warfare, this is not the case. In reality, units do not arrive in the sequence planned by the joint staff, but either

are delayed or arrive early. Units can be detained at POE's, be delayed due to weather or simply never arrive (i.e. attrition of shipping by enemy submarines). If units arrive early they may cause congestion at their POE, affecting forces arriving later.

A methodology for evaluating a mobilization plan must capture the synergistic effects between forces on the battlefield at any particular time caused by the stochastic nature of a CAX. Each arriving unit contributes to the overall force readiness in a different way. For instance, the absence of a certain logistic unit will adversely affect the combat effectiveness of the forces it supports. An analogy can be drawn to a chess game, where the outcome of the game can be different depending on which pieces are present, because each piece contributes differently. This thesis seeks to demonstrate a methodology that captures the total force readiness based on both the strength and location of friendly and enemy forces. To fully measure the relative strength of Blue vs. Red, aggregate measures were developed which capture the spatial and temporal relationships between opposing forces. The friendly and enemy forces must first be divided into two sets. One set consists of forces already present in theater when the game begins and the other consists of forces that arrive in theater during the CAX. For each set contained in the Red and Blue forces (i.e. Red 1, Red 2, Blue 1, Blue 2) a strength weighted center of mass (centroid) is calculated. The relative location of Red and Blue weighted centroids can be analyzed over a period of time to show relative force strengths and can be used as a measure to determine the effectiveness of a particular mobilization plan. Similarly this methodology can also be applied to the entire Red or Blue force. A

discussion of potential measures developed through application of this methodology follows. Definitions of the terms used in the discussion are given in Table 3.

Indices	Definition
i	Set
j	Force (i.e. blue or red)
t	Time
Variables	**Definition**
strength	Unit Strength
location	Unit Location (lat-long)

Table 3. Definition of Variables and Indices

1. Calculation of Unit Strength

JTLS represents each individual unit as an entity which is described in terms of its attributes. One of the attributes is the status of the Combat Systems possessed by the unit. JTLS Combat Systems represent weapons such as tanks, fighting vehicles, artillery, and support assets such as combat and service support equipment and personnel . Ground units consume supplies, which need to be resupplied. If a unit does not have sufficient supplies, its Combat Systems' performance will be degraded or the unit will be rendered incapable. An example of how logistics can affect a unit's combat effectiveness is when they run out of fuel. When an M-1 tank reaches zero fuel state, its combat effectiveness is reduced to 60% as opposed to a 155 self-propelled howitzer which is reduced to 98%. Similar degradations of combat systems are represented for other Combat and Service

Support Functions. This information is stored in the Combat System characteristics array. A small sample of the Combat System Characteristic Array for several arbitrarily chosen systems is shown in Table 4.

NAME	WGT. (TONS)	RESUPPLY CAT	EFFECTIVE RANGE (KM)	ATTRITION TYPE	NO FUEL EFF	SUPPLY CAT TO FIGHT
INFANTRY	0.15	1	0.3	1	1.0	6
155 SP HOWITZER	30	7	18.6	2	0.98	6
M-1 TANK	60	7	3.5	1	0.6	6
TANKER TRUCK	2.73	7	0	0	1.0	0
C3	1.0	0	0	0	1.0	0

Table 4. Example of Combat Characteristics Array

JTLS models attrition using Lanchester equations. Column 5 of Table 4 lists the attrition coefficients with 1 representing direct fire, 2 for indirect fire, and 0 indicating a system that is a non-attritor. One noteworthy observation is that although a tanker truck will never cause attrition, it can be a potential target, subject to attrition from the opposing side. Furthermore, although the tanker truck does not cause attrition, it does contribute to the overall effectiveness by providing fuel to the systems which do cause attrition. As evidenced previously with the example of the M-1 tank, non-attriting systems contribute to combat effectiveness indirectly through the systems that they support.

JTLS reports a unit's current strength in terms of percent capable. To determine the strength at any given time the unit's full (or 100%) strength must be calculated and multiplied by the percent capable available through the post-processor. Table 5 illustrates

how full strength for a unit containing the listed Combat Systems is calculated. Column 2, the number of each combat system, is the number the unit is authorized at the start of the game. Simply multiplying the number authorized by the value of an individual system and summing over each combat system gives the value of a unit's full strength. In this example the unit's full strength is 1500. At any time during the game this unit's current strength can be attained by multiplying its percent capable by 1500.

NAME	NUMBER	VALUE	NUMBER*VALUE
INFANTRY	500	1	500
M-1 TANK	17	30	510
155 SP HOWITZER	24	10	240
SUPPORT PERSONNEL	300	0.5	150
C3	1	100	100
			1500

Table 5. Example Combat System Structure

2. Weighted Centroid

For each set, i, of a force, j, a weighted centroid is calculated at time, t, using equations (1) and (2), based on the position and current strength of units contained in each set. Appendix D shows an example of a weighted centroid calculation.

$$LAT_{i,j,t} = \frac{\sum_{k} LAT_{i,j,t,k} \bullet STRENGTH_{i,j,t,k}}{\sum_{k} STRENGTH_{i,j,t,k}} \qquad (1)$$

$$LONG_{i,j,t} = \frac{\sum_k LONG_{i,j,t,k} \bullet STRENGTH_{i,j,t,k}}{\sum_k STRENGTH_{i,j,t,k}} \qquad (2)$$

where $k = 1,\ldots,k_{i,j}$, the number of units in set i, of force j

3. Distance between Weighted Centroids

As Blue units arrive in theater they change the relative distances between Blue and Red weighted centroids. Examining the movement over time of the relative positions of weighted centroids can provide insight into the effectiveness of a mobilization plan. Examples of movements of Red and Blue Centroids are shown in Figure 3 and Figure 4. A single figure is not used because of the fidelity required to illustrate the movements of centroids in response to changes in location and strength of Blue and Red units. At any given time, once the locations of the Red and Blue centroids are known, the algorithm for calculating Great Circle distances across the earth contained in JTLS is easily adapted and used in a spreadsheet to calculate the distance between the two centroids, which is then plotted over time. Examination of the distances between centroids over time provides insight into the effectiveness of a mobilization plan. Similar to how the outcome of a chess game is dependent upon what pieces are present on the board at any given time the outcome of a battle is dependent upon what mix of forces are in theater and their proximity to the enemy. Appendix E shows an example of the distance between centroid calculation.

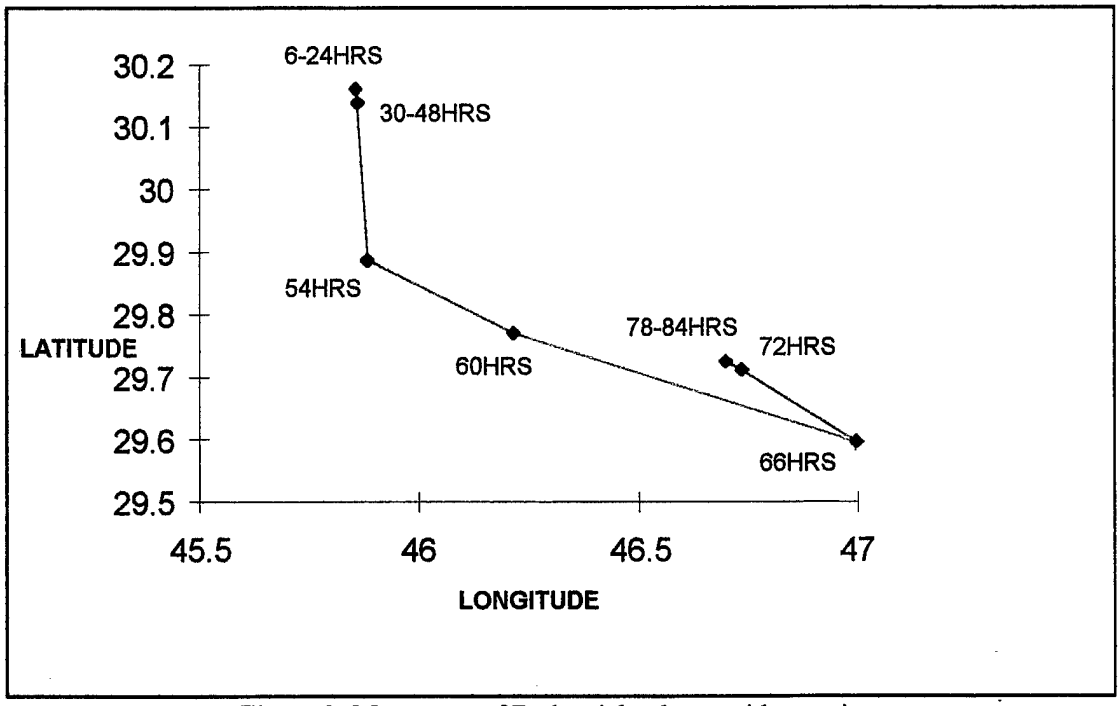


Figure 3. Movement of Red weighted centroid over time

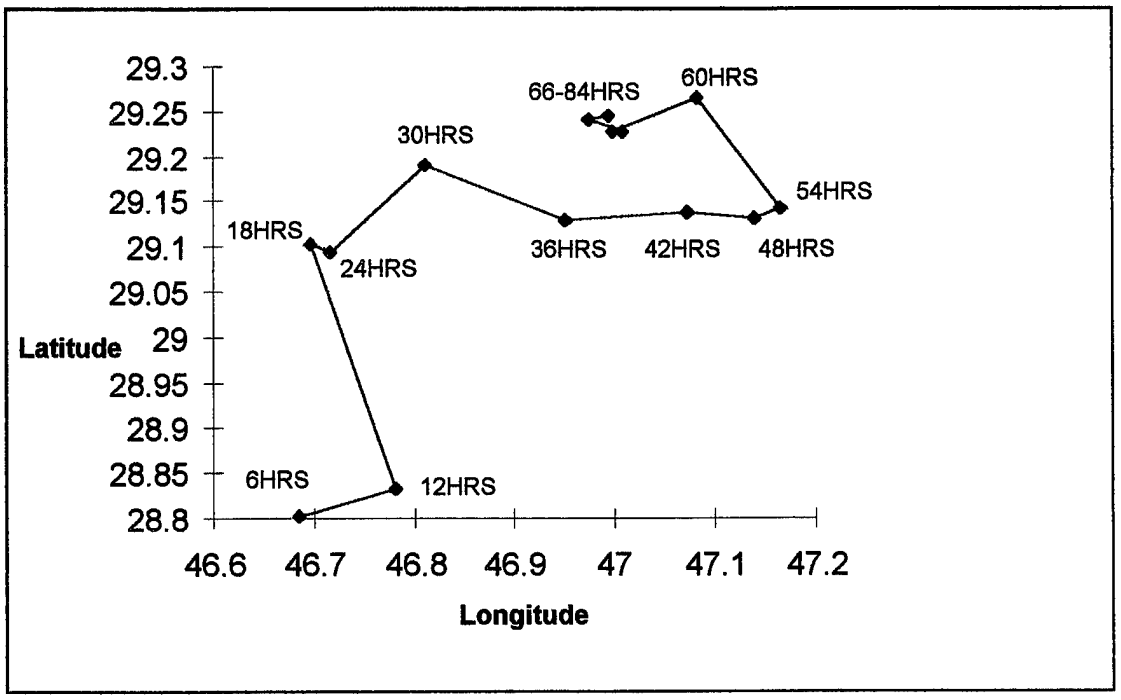


Figure 4. Movement of Blue weighted centroid over time

IV. JTLS APPLICATION

This chapter demonstrates an application of the practical methodology for evaluating the effectiveness of a mobilization plan as described in Chapter III. Specifically it shows that a simulation can furnish the data necessary to develop meaningful measures of performance in a relatively simple manner with very few calculations. It is important to emphasize that this thesis is not intended to demonstrate tactics or to evaluate the performance of the computer model. Figures 8 through 19 which show how the distance between the strength weighted centroids of the opposing sides change over time, are all provided at the end of the chapter to facilitate the multiple comparisons required.

A. SCENARIO

Essential to a successful CAX is a well planned scenario. The first step in developing a scenario is to decide what *effects* are being sought and determine what composition of forces on both sides will be necessary to bring about these *effects*. Once the desired *effects* are created, data are extracted and the methods discussed in Chapter III are applied. The scenario developed for this demonstration was designed to create interactions between the two sides that provided data for the six theses mentioned in Chapter I.

B. SCENARIO DEVELOPMENT

Two scenarios were developed based upon a Major Regional Conflict (MRC) in Southwest Asia. One scenario is called Heavy and the other Light. Each scenario has two variants. In variant 1 (i.e. Heavy 1 and Light 1), arriving Blue forces are delayed from reaching their assigned sectors within theater. In variant 2 (i.e. Heavy 2 and Light 2), arriving Blue forces are not delayed and reach their assigned sectors in theater as planned. One instance of each scenario and variant was simulated using primary combat units (i.e. infantry, armor, ships) and their associated logistical support elements. As mentioned in Chapter III, Blue and Red forces were partitioned into two sets each. Set 1 represents forces positioned in theater at the beginning of the game and Set 2 are the forces which arrive during the game.

C. HEAVY SCENARIO

1. Heavy 1

At the start of this scenario, Iraq (Red) has moved south with the immediate objective of seizing the Trans-Arab pipeline. Red forces have displaced all Gulf Coalition (i.e. Kuwaiti and Saudi Arabian) or Green forces from Kuwait. The Iraqi forces have taken up defensive positions north of King Khalid Military City (KKMC) and along the Kuwaiti-Saudi-Arabian border in the east. Blue (US, UK and Coalition) forces in Set 1 are shown in Table 6, while Red forces in Set 1 are shown in Table 7. In this scenario,

all Red forces are present at the beginning of the game; therefore, there is no Red Set 2. Blue Set 2 is shown in Appendix A. Figure 5 shows all forces present at the start of the game. Note that the green icons represent Coalition forces, blue represents US and UK forces and red represents Iraqi forces. For this particular application, the term Blue forces includes US, UK and Coalition forces (i.e. blue and green icons in Figure 5).

Unit	Country
10MXINBD	Saudi Arabia
11MXINBD	Saudi Arabia
13MEU.SOC	USA
1ARDIV.UK	UK
20INBDEMX	Saudi Arabia
24MEU.SOC	USA
2BDE24MX	USA
2INDIV.UK	UK
3UKSPTBN	UK
8MXINBD	Saudi Arabia
EADIVCMD	Kuwait
HQ24MECH	USA
HQ3BDE101	USA
JFCMD.KU	Saudi Arabia
MSSG.13	USA
MSSG.24	USA
NODIVCMD	Kuwait
NWARECMD	Saudi Arabia

Table 6. Blue Forces in Set 1 for Heavy 1 and Heavy 2

Unit	Country
108INBDE	Iraq
17ARDIV	Iraq
28DISCOM	Iraq
28DIVARTY	Iraq
28INDIV	Iraq
38ELECMEC	Iraq
38ENGBN	Iraq
38IDCMDO	Iraq
38LTADABN	Iraq
412INBDE	Iraq
417INBDE	Iraq
78INBDE	Iraq
HAMMURABI	Iraq
MADINAH	Iraq
RGFCFA.IQ	Iraq

Table 7. Red Forces in Set 1 for Heavy 1 and Heavy 2

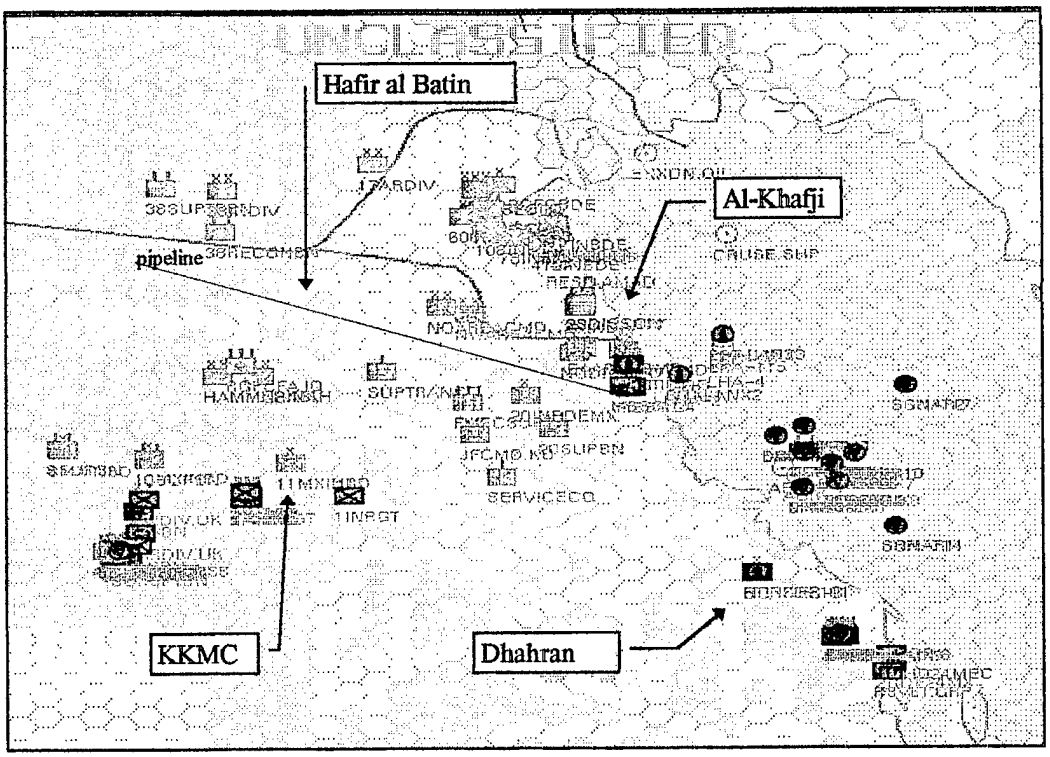


Figure 5. Initial Force Locations at Start of Heavy 1 and Heavy 2

One hour into the game the 2nd Brigade of the 24th Mechanized Infantry Division (2/24 Mech) and 3rd Brigade of the 101st Airborne Division (3/101 ABD) arrive and have been joined by their subordinate units. The 2/24 Mech begins to move toward KKMC and the 3/101 ABD begins to move towards Khafji in the north. The 2/24 Mech is slowed by Red airstrikes as it moves west.

Blue forces arrive into theater unhampered until 281400ZDEC90 when the port at Dhahran is hit with an aerial attack. This causes units arriving through this port to be processed slower than usual for the next 12 hours because of the damage to the port's Material Handling Equipment (MHE). A queue builds up as units wait at the port to be

processed. As MHE is repaired, units waiting are processed according to their priority assigned in the TPFDD.

Shortly into the second day the Iraqi 17th Armor Division begins to withdraw after an engagement with Coalition forces leaves them severely damaged. Two other significant events occur on the second day. One is closure of the 1st Brigade of the 101st Airborne Division (1/101 ABD) and 1st Brigade of the 24th Mechanized Infantry Division (1/24 Mech) and their movement toward Khafji and KKMC respectively. The other is a Red attack on the USMC units in the east. By midday enough Blue units have arrived to begin counterattacks in the West north of KKMC and in the east near Khafji.

By the beginning of the third day, Red forces in both the east and west have been damaged to the point where they begin to withdraw. By midday, Blue forces have pushed Red forces out of Kuwait and continue to pursue them until the end of the game.

2. Heavy 2

This scenario allows Blue forces to arrive in theater and deploy to their assigned positions without interruption. Red forces take no offensive actions and thus allow the Blue forces to establish the tempo of engagements. The port at Dhahran is not damaged and therefore forces arriving through Dhahran are not delayed. The Iraqi 17th Armor Division is stopped by Blue air attacks before it can engage Blue forces in the west.

Midday on the third day, Blue begins its counterattack in the north and west. By late in the day, the Red forces begin to withdraw and Blue forces pursue them with results similar to Heavy 1.

3. Discussion

Figures 8 through 13 show how the distance between strength weighted centroids of Blue and Red forces changes throughout the Heavy scenarios. Figures 8 and 11 are for Set 1. Figures 9 and 12 are for Set 2 and Figures 10 and 13 are for the entire Blue and Red forces. By comparing and contrasting the displayed results, insight into how effective a particular mobilization plan was in moving forces into theater in relation to the opposing forces can be gained. In particular, times at which a significant change in the direction of the strength weighted centroid indicate potential critical event occurrences. The causal reasons for this change would then be investigated using methodologies described in References 1 through 6.

In Heavy 2, because the Red forces took no offensive action prior to the Blue counter-offensive, the curve in Figure 11 is flat until approximately 60 hours. into the game, which coincides with the time the Blue counter-offensive happened. During a similar period in Heavy 1, the engagement between the Iraqi 17th Armor Division and the Gulf Coalition forces in the west is manifested by the behavior of Figure 8. The two strength weighted centroids get closer during the battle and then open up as the 17th Armor Division begins to withdraw. Intuitively, this comparison makes sense, because one would expect a flat curve during a period when nothing significant is happening as in Figure 11 and behavior like Figure 8 during an engagement and withdrawal.

Examination of Figures 8 through 13 reveals different behavior for each scenario during Red's withdrawal. In Heavy 2, which occurred approximately 66 hours into the game, the distances increased (Figure 13) while during Red's withdrawal in Heavy 1,

which occurred approximately 48 hours into the game, the curves were either flat or decreasing (Figure 10). This can be explained by the fact that 48 hours into Heavy 1, Blue forces were still transiting from their points of entry and therefore skewed the strength weighted centroid away from the Forward Edge of the Battle Area (FEBA), while in Heavy 2 all forces had already transited from their points of entry to a position close to the FEBA prior to the Red withdrawal.

D. LIGHT SCENARIO

This scenario also begins on 280000ZDEC90. In this scenario, the Red forces have not entered Kuwait, but are only threatening to invade. US forces are able to flow into Doha, Dhahran, and King Fahd International Airport (KFIA). At the beginning of the game, two Marine Expeditionary Units are poised near Doha, the 3rd Brigade of the 101st Airborne Division (3/101 ABD) is moving north toward Kuwait, and the 2/24 Mech is moving west towards KKMC. Initial force locations are shown in Figures 6 and 7. Red and Blue Set 1 and Set 2 forces are shown in Appendix A.

1. Light 1

Forces flow into theater unhampered for the first 5 hours of the game until airstrikes again damage port operations. The results are similar to Heavy 1 in that arriving forces are detained at the port while MHE is repaired. Red initiates an offensive 18 hours into the game, long before all Blue forces have arrived in theater. The 3/101 ABD

conducts a heliborne assault into northern Kuwait in an attempt to repulse the Red offensive.

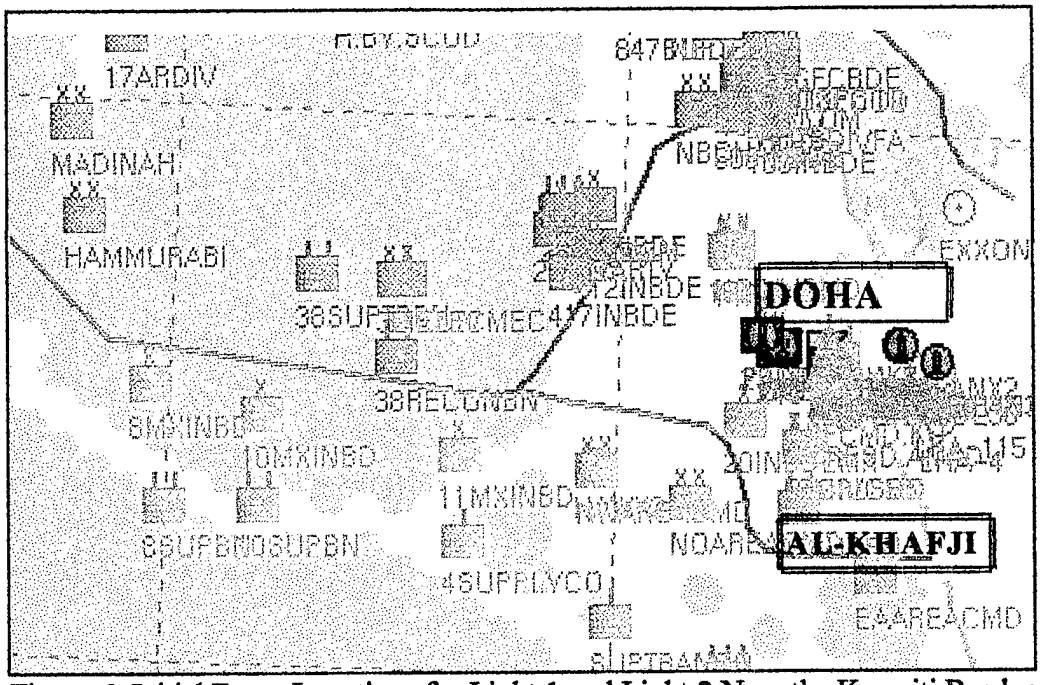


Figure 6. Initial Force Locations for Light 1 and Light 2 Near the Kuwaiti Border

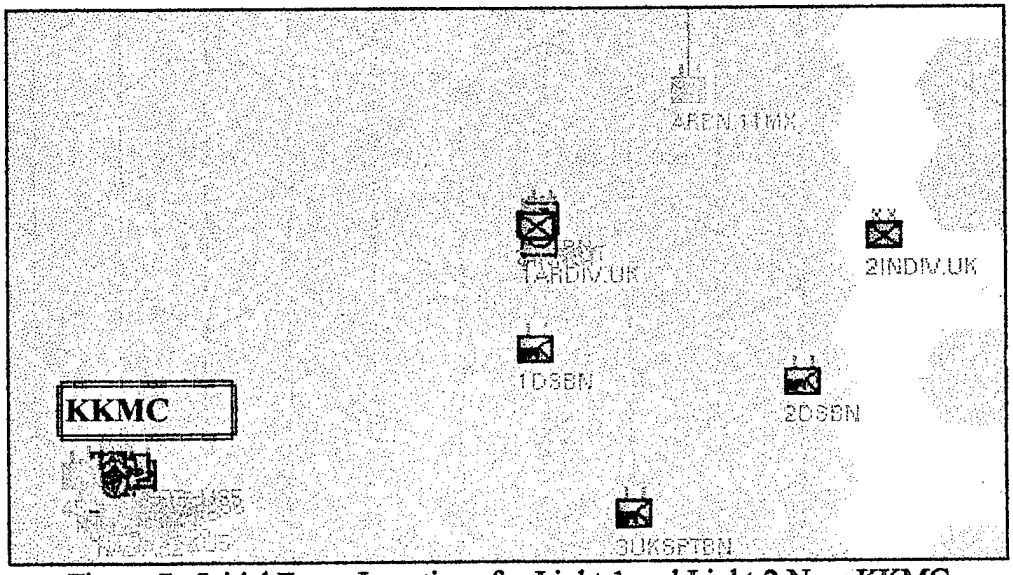


Figure 7. Initial Force Locations for Light 1 and Light 2 Near KKMC

Blue forces already in position, coupled with arriving Blue forces, are able to hold off the Red attack. Red forces begin to withdraw between 24-30 hours into the game and are pursued by Blue forces.

2. Light 2

This scenario is very similar to the one previously discussed with the major difference being that the port operations are not hampered and thus the majority of Blue forces are able to flow into theater before the onset of hostilities. The heliborne assault is also not conducted which allows the Red forces deeper penetration into Kuwait. Similar to Light 1, Red forces are repulsed out of Kuwait and pursued into Iraq.

3. Discussion

Figures 14 through 19 show how the distance between strength weighted centroids of Blue and Red forces changes throughout the two scenarios. Figures 14 and 17 are for Set 1. Figures 15 and 18 are for Set 2 and Figures 16 and 19 are for the entire Blue and Red forces.

In these particular scenarios, there was little difference in the outcome or in the flow of battle within the theater caused by arriving forces. In Light 1 the hostilities begin before the majority of Blue forces have arrived, while in Light 2 hostilities begin soon after the majority of Blue forces have arrived in theater. However, Blue participation in the significant engagements of the campaign were for the most part limited to Set 1. The Red offensive 18 hours into the game is evidenced by the steep decline in Figure 14, but after that Figure 14 and Figure 17 appear to be very similar. Examination of Figure 15 and Figure 18 reveals that both curves are almost the same shape and cover a very similar

range. The major difference between the two curves is that the downward sloping portion is shifted to the right approximately 18 hours, which corresponds closely with the time that several of the Set 2 units were delayed. Examination of Figure 16 and Figure 19 shows a similar relationship to the previous discussed curves.

Another noteworthy observation is from Figures 17 through 19 where it can be seen that the Red penetration into Kuwait was deeper than in Light 1 as shown in Figures 14-16, possibly due in part to the lack of a Heliborne assault in Light 2. This reveals that the methodology developed in this thesis has other possible applications in examining effectiveness of operational maneuver similar to CPT Kevin Brown's thesis [Ref. 4].

E. SUMMARY

This chapter has demonstrated several possible insights into the effectiveness of a particular mobilization plan. The methodology is intended to provide for post exercise analysis by examining, over time, how the relative strength weighted centroids of opposing forces move. This methodology is similar to taking a series of snapshots over time of a chess board and displaying graphically how the two sides compare relative to each other. This experiment conducted using JTLS has established how, with only limited interaction with the model, all of the information necessary to implement the methodology can easily be displayed.

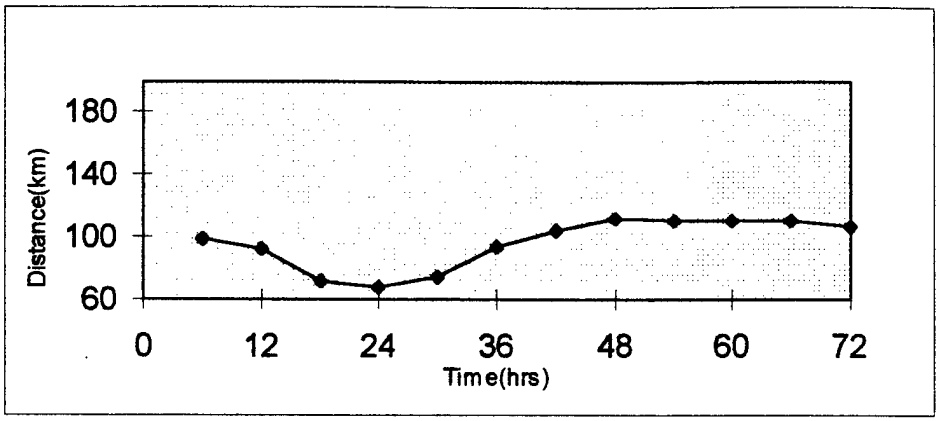


Figure 8. Distance Between Weighted Centroids of Blue Set 1 and Red Forces for Heavy 1

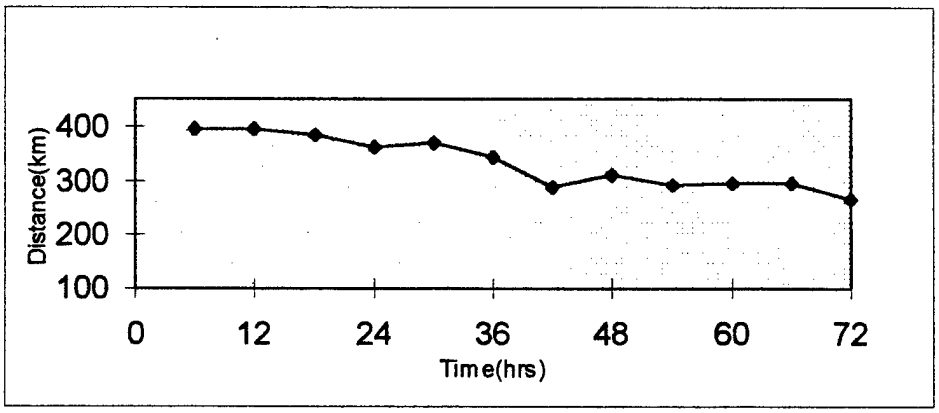


Figure 9. Distance Between Weighted Centroids of Blue Set 2 and Red Forces for Heavy 1

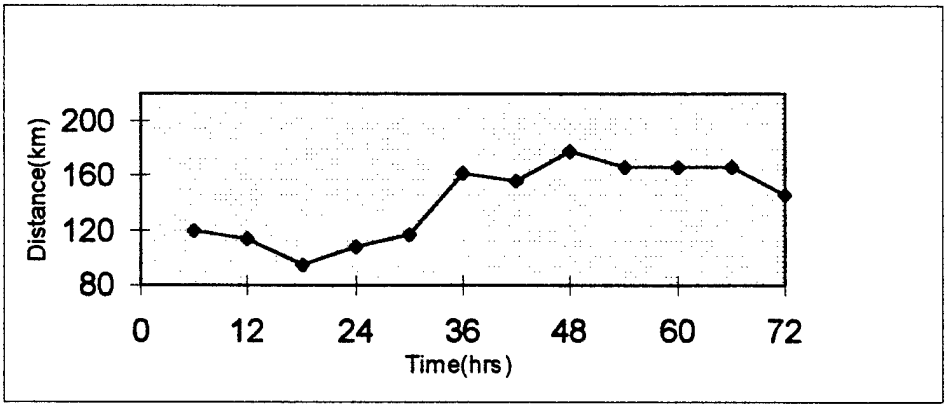


Figure 10. Distance Between Weighted Centroids of All Opposing Forces for Heavy 1

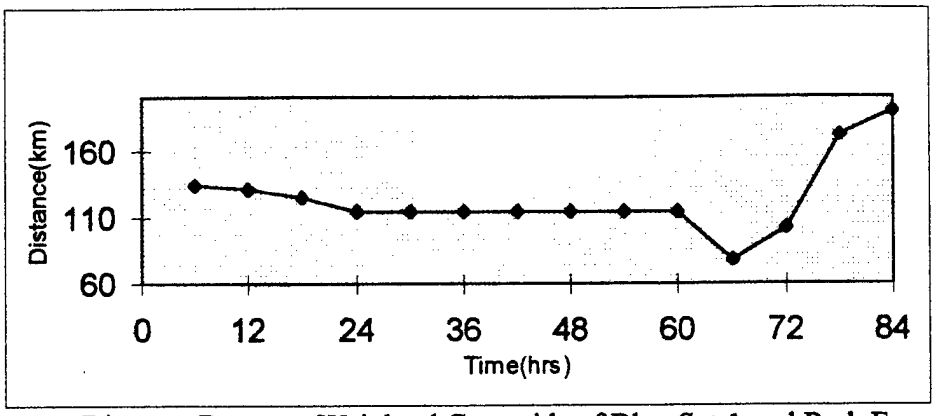


Figure 11. Distance Between Weighted Centroids of Blue Set 1 and Red Forces for Heavy 2

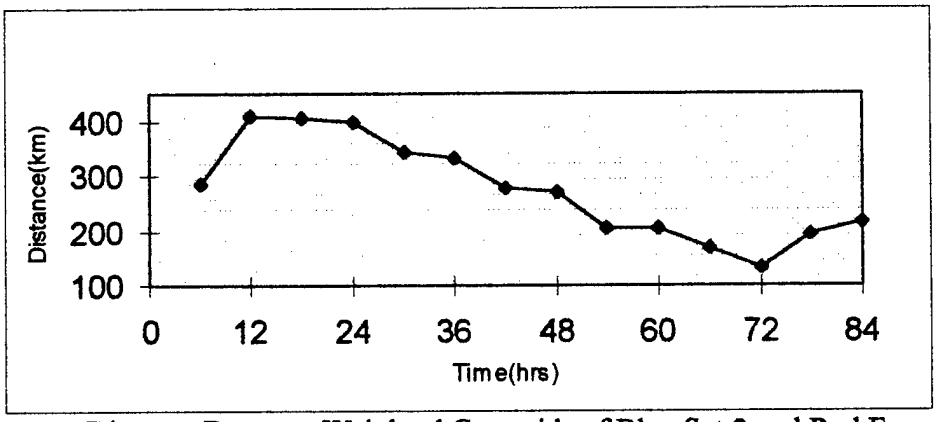


Figure 12. Distance Between Weighted Centroids of Blue Set 2 and Red Forces for Heavy 2

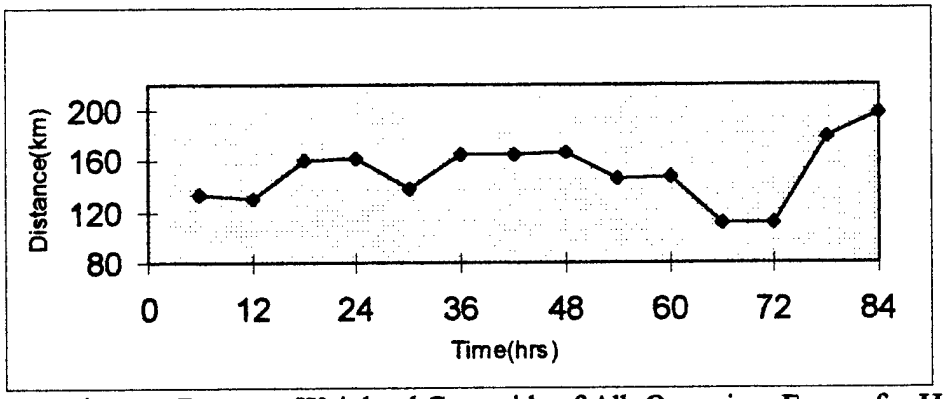


Figure 13. Distance Between Weighted Centroids of All Opposing Forces for Heavy 2

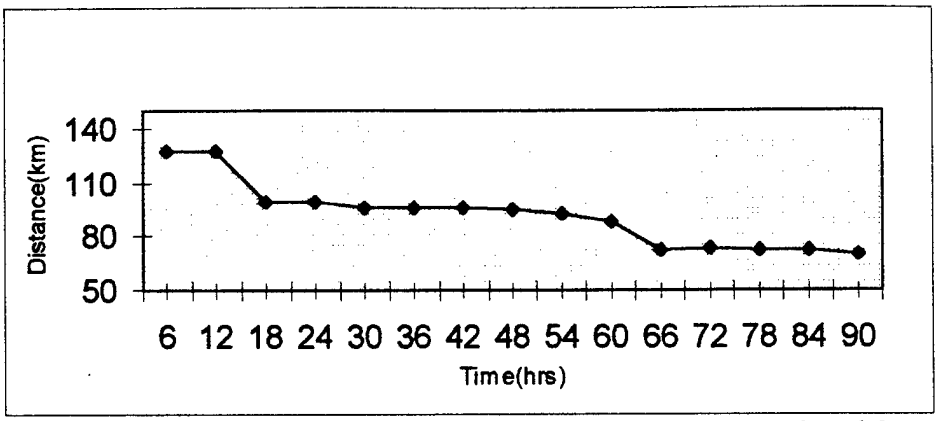


Figure 14. Distance Between Weighted Centroids of Blue Set 1 and Red Set 1 for Light 1

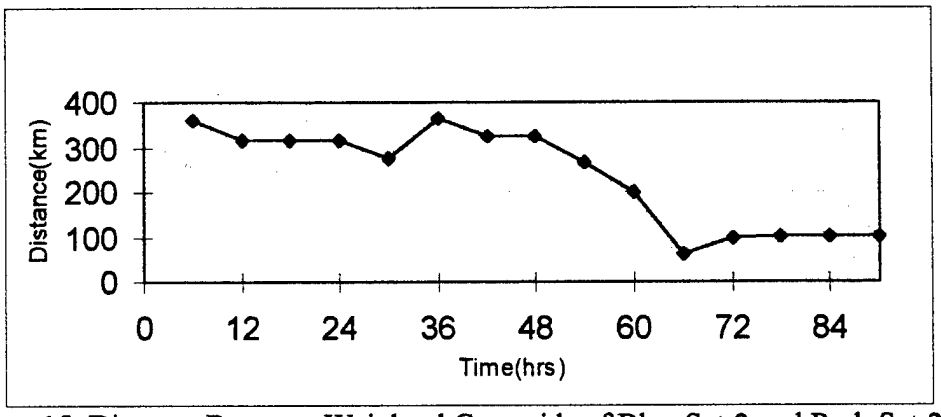


Figure 15. Distance Between Weighted Centroids of Blue Set 2 and Red Set 2 for Light 1

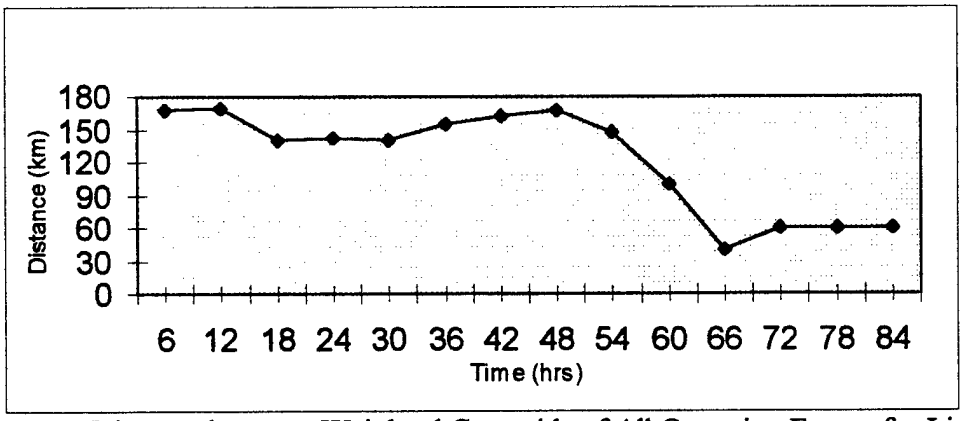


Figure 16. Distance between Weighted Centroids of All Opposing Forces for Light 1

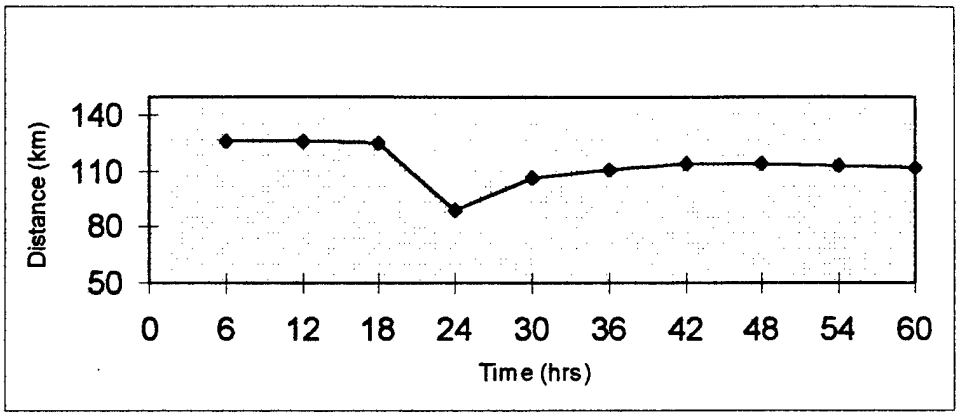


Figure 17. Distance Between Weighted Centroids of Blue Set 1 and Red Set 1 for Light 2

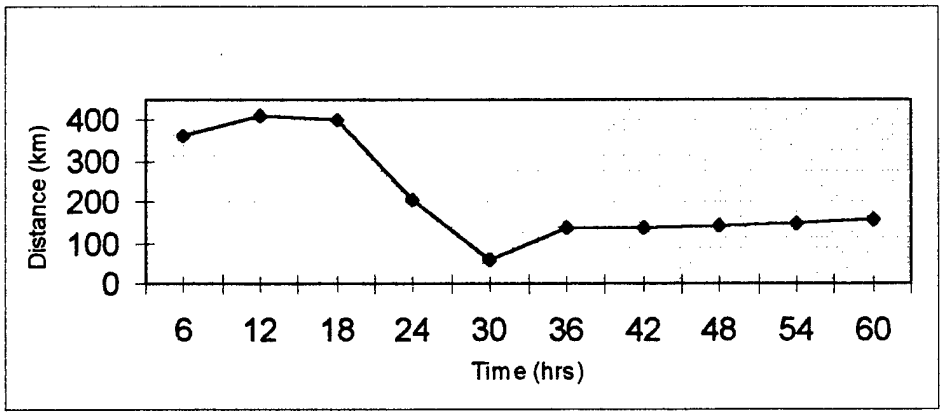


Figure 18. Distance Between Weighted Centroids of Blue Set 2 and Red Set 2 for Light 2

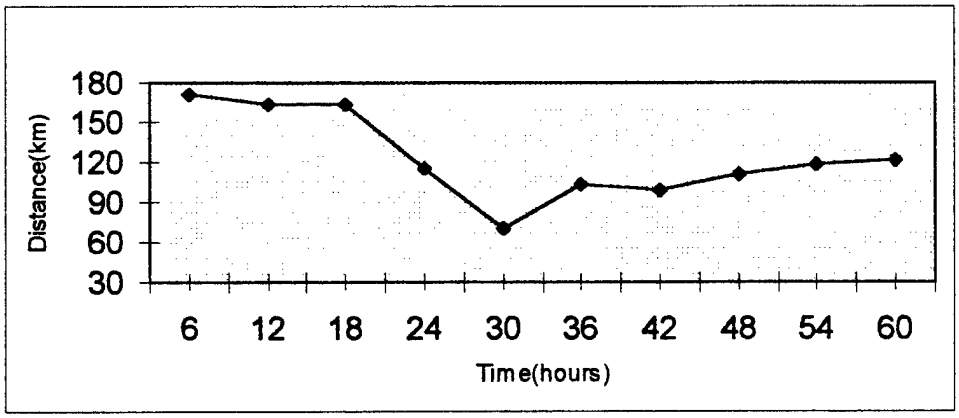


Figure 19. Distance Between Weighted Centroids of All Opposing Forces for Light 2

V. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

This research has provided a methodology for evaluating the effectiveness of a mobilization during a computer aided exercise. The methodology presented does not seek to assign values to each individual joint mobilization task stated in the UJTL, but instead seeks to determine how the outcome of significant events was impacted by the mix of forces present in theater and their location relative to the enemy at the time the event took place. The first step in the implementation of the methodology is to partition the opposing forces into sets. Once the sets have been identified, the methods described in Chapter III can be applied. It is important to note that this methodology can be applied to any set of units regardless of side or faction. Lastly, by creating graphs similar to Figures 8 through 19 distance between the strength weighted centroids of any two sets of units can be observed over time, allowing the user to determine how effective the arrival and placement of forces on the battlefield has been.

One strength of this methodology is that it is relatively simple , but retains the robustness to be applicable in many different scenarios. Because it is simple to implement, it allows for quick analysis that can easily be presented in post exercise debriefings. Another strength is that it requires no special player interactions with the model since the data necessary to use the methodology is easily output to the post processor.

B. RECOMMENDATIONS

Another possible application of the model is to explore how effectively forces are employed once in theater. For example, if the arriving units are given orders to proceed to a position where there is no enemy threat or given orders to proceed to an area where an enemy threat does exist, the changing location of the strength weighted centroid relative to the opposing force would provide a good indication of the overall effectiveness of the movement orders. In other words, just as it is important to know if the right mix of forces is on the battlefield, it is important to determine if they were utilized properly. It is recommended that this methodology be applied in conjunction with that presented in CPT Kevin Brown's thesis [Ref. 4].

Because JTLS is an event driven, discrete time simulation, changes in strength and location are sent to the post processor as shown in Appendix C. This methodology uses both current strength and position and it becomes quite cumbersome. When either strength or location changes, it is necessary to sort through the other post processor file in order to match up the current pair (strength and location). It is not very difficult to write computer code to search each post processor file for the data that are needed and then merge the two files, but it is time consuming. The sorting and merging consumes the bulk of the time when applying this methodology. If strength and location could be linked so that if either one changed, they would be both be sent to the same post processor file, then the amount of time needed to apply this methodology would be significantly reduced. For example the entire methodology could be applied using a spreadsheet package in a

timely enough manner to be useful in a post CAX debrief before all of the important players have dispersed.

This thesis must be viewed as part of the whole effort to evaluate overall performance of a Joint Staff. This thesis, along with the theses mentioned in Chapter I, addressing operational maneuver, force protection, operational firepower and short term logistic support of amphibious operations as well as those previously completed concerning theater logistics and intelligence tasks provide the baseline for future efforts to develop a standard methodology for evaluating Joint Staff performance. Standardized methods for evaluating the decision making process of a Joint Staff will provide a causal audit trail for success or failure and further enrich the training benefits available to a Joint Staff during a CAX.

APPENDIX A. FORCES IN SET 1 AND SET 2

The spreadsheets contained in this appendix show the units in the sets not displayed in the main body of the text.

Unit	Country
1-11FABN	USA
1-159AVBN	USA
1-227AVBN	USA
1-229ATKH	USA
1-3ARMCAV	USA
1-AVBN101	USA
101AVNBDE	USA
101DISCOM	USA
101DIVFA	USA
11FABDE19	USA
159AVNGP	USA
18AVNBD19	USA
18COSCOMF	USA
18COSCOMR	USA
1ARBDE1AR	USA
1ARMDIV	USA
1BDE24MX	USA
1DISCOMF	USA
1DISCOMR	USA
1FARP.101	USA
1FARP24MX	USA
2-11FABN	USA
2-159ATKH	USA
2-2ADABN	USA
2-AVBN102	USA
229ATKGP	USA
24AVNBN	USA
24DISCOMF	USA
24DISCOMR	USA
24DIVARTY	USA
2ADABDE18	USA
2ARBDE1AR	USA
3-11FABN	USA
3-229AHB	USA
3-2ADABN	USA
3ARBDE1AR	USA
3ARCAVRGT	USA
3MEF.HQF	USA
4-17CAB19	USA
4-3AIRCAV	USA
4-AVBN101	USA
5-AVBN101	USA
6-AVBN101	USA
7-AVBN101	USA
7COSCOM	USA
9FABDEVII	USA
A-3AHB101	USA
HQ101ABD	USA
HQ1BDE101	USA
HQ2BDE101	USA
VIICORPS	USA
VIIFA	USA
XVIIIABC	USA
XVIIIFA	USA

Blue Forces in Set 2 For Heavy 1 and Heavy 2

Unit	Country
10MXINBD	Saudi Arabia
11MXINBD	Saudi Arabia
13MEU.SOC	USA
1ARDIV.UK	UK
1DSBN	UK
20INBDEMX	Saudi Arabia
24DISCOMF	USA
24MEU.SOC	USA
2BDE24MX	USA
2DSBN	UK
2INDIV.UK	UK
3UKSPTBN	UK
8MXINBD	Saudi Arabia
EAAREACMD	Saudi Arabia
EADIVCMD	Kuwait
HMH-461	USA
HMH-463	USA
HMM-162	USA
HMM-261	USA
HQ24MECH	USA
HQ3BDE101	USA
MSSG.13	USA
MSSG.24	USA
NOAREACMD	Saudi Arabia
NODIVCMD	Kuwait
NWAREACMD	Saudi Arabia

Blue Forces in Set 1 for Light 1 and Light 2

Unit	Country
1-11FABN	USA
1-159AVBN	USA
1-227AVBN	USA
1-229ATKH	USA
1-2ADABN	USA
1-320FABN	USA
1-3ARMCAV	USA
1-41FABN	USA
1-AVBN101	USA
101AVNBDE	USA
101DISCOM	USA
101DIVFA	USA
11FABDE19	USA
159AVNGP	USA
18AVNBD19	USA
18COSCOMF	USA
18COSCOMR	USA
1ARBDE1AR	USA
1ARMDIV	USA
1BDE24MX	USA
1DISCOMF	USA
1DISCOMR	USA
1ENBDE	USA
1FARP.101	USA
1FARP24MX	USA
2-11FABN	USA
2-159ATKH	USA
2-2ADABN	USA
2-AVBN101	USA
229ATKGP	USA
24AVNBN	USA
24DISCOMR	USA
24DIVARTY	USA
2ADABDE18	USA
2ARBDE1AR	USA
3-11FABN	USA
3-229AHB	USA
3-2ADABN	USA
3ARBDE1AR	USA
3ARCAVRGT	USA
3ARMY.ASG	USA
4-17CAB18	USA
4-3AIRCAV	USA
4-AVBN101	USA
5-AVBN101	USA
6-AVBN101	USA
7-AVBN101	USA
7COSCOM	USA
HQ101ABD	USA
HQ1BDE101	USA
HQ2BDE101	USA
VIICORPS	USA
VIIFA	USA
XVIIIABC	USA
XVIIIFA	USA

Blue Forces in Set 2 for Light 1 and Light 2

Unit	Country
108INBDE	Iraq
16ARTYBN	Iraq
28DISCOM	Iraq
28DIVARTY	Iraq
28INDIV	Iraq
38ELECMEC	Iraq
38ELECMEC	Iraq
38ELECMEC	Iraq
38ENGBN	Iraq
38IDCMDO	Iraq
38LTADABN	Iraq
38RGFCBDE	Iraq
38SUPTRBN	Iraq
412INBDE	Iraq
417INBDE	Iraq
606INBDE	Iraq
78INBDE	Iraq
847INBDE	Iraq
HQ16DIVFA	Iraq
NBCHANEZR	Iraq

Red Forces in Set 1 for Light 1 and Light2

Unit	Country
17ARDIV	Iraq
MADINAH	Iraq
HAMMURABI	Iraq

Red Forces in Set 2 for Light 1 and Light2

APPENDIX B. TUP SCORES USED IN JTLS

The data in the following spreadsheet are taken from the On Line Players Manual in JTLS. The number represents the overall firepower score for a unit using any of the 84 prototypes. This score is not used in determining battle outcome, but does impact on the capabilities and resupply of a unit. These scores are the values discussed in the development of unit strength and are aggregated for all systems in the identified unit.

TUP #		PROTOTYPE		SCORE
1		MECHBN.2		2790
2		SFBN		235
3		BNHQ		184
4		MECHBN.3		2874
5		INFBN.1		2040
6		INFBN.3		1557
7		ARBN.1		6230
8		ARBN.2		2208
9		ARMCAVSQ.2		1757
10		FABNSP.1		3987
11		FABNSP.2		4054
12		ADAINF.1		754
13		DISCOM.IN		1748
14		STCO.1		543
15		HHAVNBN.1		6134
16		HHAVNBN.2		840
17		UHAVNBN.1		5379
18		UHAVNBN.2		840
19		AHAVNBN.1		4430
20		AHAVNBN.2		1040
21		NAVAIR.1		1330
22		MARAIR.1		1540
23		AFAIR.1		2833
24		AIRLIFT.1		2033
25		BOMTRAN.1		1233
26		AIRRGT.2		6146
27		ENGINF.1		1283
28		FARP.1		322
29		DIVHQ.1		384
30		INDIVHQ.1		468
31		MXDIVHQ.1		868
32		ARDIVHQ.1		1168
33		ABNDIVHQ.1		468
34		ASLTDVHQ.1		468
35		ABNBDEHQ.1		207
36		ASLTBDHQ.1		207
37		ARBDEHQ.1		207
38		MXBDEHQ.1		207
39		INFBDEHQ.1		207
40		MRR.2		10434
41		MRD.2		48673
42		TANKRGT.2		9355
43		TANKDIV.2		45607
44		CIVSMALL.1		3120
45		CIVILAFFAIR		155
46		CIVLG.1		30510
47		SF.ODA.1		275
48		SCUD.BATTERY		120
49		RECON.TM.3		192
50		TANKBN.3		3601
51		INFRGT.3		2696
52		MXRGT.3		3380
53		FARGT.3		4165
54		TANKRGT.3		5194
55		MLRS.1		3525
56		SF.GP.1		370
57		AIRBASE.1		880
58		IQINFDIVARTY		4165
59		FABNTWD.1		1593
60		AIRCAVSQ.1		6075

APPENDIX C. SAMPLE INPUT FILES FROM POSTPROCESSOR

This information is representative of the input files received from Rolands and Associates. The files were prepared by opening them in a spreadsheet and removing excess columns and characters. A sample from each of the location and strength files is included. The input files ranged in size between 3000 to 48000 bytes.

Location File:

Game Time	Unit Type	Unit	Latitude	Longitude	Force Side
2.635056	2	VII-300004	30.84368	46.2272	0
2.635812	2	VII-300004	30.91667	46.16667	0
1.5	1	VIICORPS	27.49725	48.51149	1
1.5	1	VIIFA	27.48891	48.5088	1
1.8	1	XVIIIABC	27.41667	48.26667	1
2	1	XVIIIFA	26.39403	50.05986	1
2.5592	3	ZSU-13	29.98023	47.34838	0
2.5592	3	ZSU-13	29.98023	47.34838	0
2.576049	3	ZSU-13	29.87511	47.30228	0
2.576049	3	ZSU-13	29.87511	47.30228	0
2.583366	3	ZSU-13	29.7712	47.30788	0
2.583366	3	ZSU-13	29.7712	47.30788	0
2.600228	3	ZSU-13	29.72952	47.43303	0

Strength File:

Game Time	Unit Type	Unit	Strength
0.001	1	JFCMD.KU	99.43
0.001	1	KAHUINBDE	99.89
0.041667	1	KHARG.BTY	99.88
0.041667	1	KU.FORCES	99.83
0.041667	1	MADINAH	99.47
2.791689	1	MADINAH	95.13
2.833356	1	MADINAH	94.23
2.875023	1	MADINAH	83.46
2.91669	1	MADINAH	61.29
3	1	MADINAH	50.32
3.000024	1	MADINAH	39.68

APPENDIX D. STRENGTH WEIGHTED CENTROID CALCULATION

The spreadsheet below shows the Strength Weighted Centroid calculation at a 6 hour checkpoint for a particular set of units. In this case the set shown is Blue Set 1 in Light 1 at 90 hours into the game.

Time	unit	Lat	Long	Full Str	% Str	% Str	Strength	Strength*Lat	Strength*Long
3.75	10MXINBD	29.0131875	45.418157	25061	99.41	0.9941	24913.1401	722809.6049	1131508.908
3.75	11MXINBD	28.8896769	46.3173995	30195	99.33	0.9933	29992.6935	866479.2246	1389183.567
3.75	13MEU.SOC	30.028944	46.998745	5417	92.93	0.9293	5034.0181	151166.2476	236592.533
3.75	1ARDIV.UK	28.546375	45.655342	24947	99.47	0.9947	24814.7809	708372.0411	1132927.309
3.75	1DSBN	28.676945	46.826111	1748	99.9	0.999	1746.252	50077.17256	81770.18999
3.75	20INBDEMX	29.0602966	47.5598833	30157	99.39	0.9939	29973.0423	871025.4992	1425514.394
3.75	24DISCOMF	29.31568	47.6864254	1748	99.52	0.9952	1739.6096	50997.83836	82955.76342
3.75	24MEU.SOC	29.8379584	46.8864957	5417	95.53	0.9553	5174.8601	154407.2604	242631.0558
3.75	2BDE24MX	29.6801475	46.9047942	25061	98.45	0.9845	24672.5545	732285.0568	1157261.091
3.75	2DSBN	28.9030595	47.1656697	1748	99.9	0.999	1746.252	50472.02546	82363.14504
3.75	2INDIV.UK	28.6091352	45.948447	18971	95.79	0.9579	18172.3209	519894.3855	834989.9237
3.75	3UKSPTBN	28.9108369	47.597179	1748	99.9	0.999	1746.252	50485.60676	83116.66902
3.75	8MXINBD	29.0698108	44.9066334	31153	99.39	0.9939	30962.9667	900087.5838	1390442.595
3.75	EAAREACMD	29.0812321	44.894298	468	99.8	0.998	467.064	13582.79659	20968.5104
3.75	EADIVCMD	28.9617051	47.8247533	17197	99.53	0.9953	17116.1741	495713.5867	818576.8038
3.75	HMH-461	29.3333333	48.25	1540	99.89	0.9989	1538.306	45123.64262	74223.2645
3.75	HMH-463	29.25	48.3666667	1540	99.89	0.9989	1538.306	44995.4505	74402.73358
3.75	HMM-162	29.25	48.3666667	1540	99.93	0.9993	1538.922	45013.4685	74432.52745
3.75	HMM-261	29.3333333	48.25	1540	99.93	0.9993	1538.922	45141.71195	74252.9865
3.75	HQ24MECH	29.728611	47.297501	868	99.54	0.9954	864.0072	25685.73395	40865.38141
3.75	HQ3BDE101	29.4800841	46.9212603	7920	99.49	0.9949	7879.608	232291.5065	369721.138
3.75	MSSG.13	29.645	47.695	10434	98.84	0.9884	10312.9656	305727.8652	491876.8943
3.75	MSSG.24	29.635	47.609	10434	99.8	0.998	10413.132	308593.1668	495758.8014
3.75	NOAREACMD	29.0812321	47.444	486	99.8	0.998	485.028	14105.21184	23011.66843
3.75	NODIVCMD	29.6737948	47.5063199	29776	99.51	0.9951	29630.0976	879237.4361	1407616.895
3.75	NWAREACMD	28.8463711	46.9282848	18550	99.26	0.9926	18412.73	531140.4425	864077.8374
				Σ strength*lat=		8092101.962			
				Σ strength*long=		12969533.68			
				Σ strength =		277510.8651			
				Strength weighted centroid =		29.15958609	46.73522845		

APPENDIX E. DISTANCE BETWEEN WEIGHTED CENTROID CALCULATION

The spreadsheet below shows the calculation for the distance between Strength Weighted Centroids for Blue Set 1 and Red Set1 in Light 1. Blue.lat, Blue.long, Red.lat and Red.long refer to the lat-long of the Strength Weighted Centroid for each force. Figures 8 through 19 are created by plotting time vs. distance.

Time	Blue.lat	Blue.long	Red.lat	Red.long	Distance
6	28.88877	46.81569	29.9973	47.21696	127.888
12	28.88878	46.81571	29.9973	47.21696	127.886
18	29.15526	46.83107	29.9973	47.21696	99.7381
24	29.15766	46.84603	29.9973	47.21696	98.9698
30	29.17192	46.84106	29.9823	47.20185	95.6171
36	29.17195	46.84094	29.98185	47.20304	95.6132
42	29.17195	46.84094	29.98373	47.20329	95.8146
48	29.17195	46.84094	29.97857	47.20351	95.2934
54	29.17183	46.84074	29.90018	47.31938	92.3147
60	29.17325	46.74429	29.85489	47.23749	88.6308
66	29.14227	46.65746	29.76138	46.92274	72.7081
72	29.14214	46.6573	29.79617	46.82237	73.68
78	29.15312	46.63386	29.79228	46.81061	72.3365
84	29.15196	46.63193	29.79494	46.81133	72.8047
90	29.16335	46.74105	29.79817	46.81146	70.1751

LIST OF REFERENCES

1. Combs, Ray, *A Methodology for Evaluating Execution of Universal Joint Tasks Within The Context of A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School, Monterey, California, Sep 1995.

2. Gordon, Kerry, *A Methodology for Evaluating The Performance of Operational Firepower During A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School Monterey, California, Sep 1996.

3. Mustin, John, *A Methodology for Evaluating Carrier Battlegroup Anti-Air Warfare Capability In A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School Monterey, California, Sep 1996.

4. Brown, Kevin, *A Methodology for Evaluating Operational Maneuver in A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School Monterey, California, Sep 1996.

5. Thurman, John, *A Methodology for Evaluating Force Protection During A Computer Aided Exercise*, Master's Thesis, Naval Postgraduate School Monterey, California, Sep 1996.

6. Cwick, Mark, *Analyzing Amphibious Logistic Capabilities In The Joint Theater Level Simulation (JTLS)*, Master's Thesis, Naval Postgraduate School Monterey, California, Sep 1996.

7. U.S. DOD, JCS, *Joint Warfare of The Armed Forces Of The United states Joint Pub 1* Washington, D.C., January 1995.

8. Joint Chiefs of Staff, CJCSM 3500.04, *Universal Joint Tasks List,* version 2.1, The Pentagon, Washington, D.C., May 1995.

9. U.S. DOD, JCS, *Joint Doctrine for Mobilization Planning Joint Pub 4-05* Washington, D.C., June 1995.

10. U.S. DOD, JCS, *Joint Operation Planning and Execution System Volume I Joint Pub 5-03.1* Washington, D.C., January 1995.

INITIAL DISTRIBUTION LIST

No. of Copies

1. Defense Technical Information Center.....2
   8725 John J. Kingman Road, Ste 0944
   Ft. Belvoir, Virginia 22060-6218

2. Dudley Knox Library.....2
   Naval Postgraduate School
   411 Dyer Road
   Monterey, California 93943-5101

3. Dr. Sam Parry, Code OR/Py.....10
   Naval Postgraduate School
   Monterey, California 93943-5002

4. Joint Warfighting Center.....3
   Attn: Maj Greg Brouillette
   Bldg 96 Fenwick Road
   Fort Monroe, Virginia 23651

5. LT Mark Sullivan.....3
   203 Normandy Rd
   Seaside, California 93955

6. Joint Warfighting Center.....3
   Attn: LTC Bob Bolling
   Bldg 96 Fenwick Road
   Fort Monroe, Virginia 23651

7. Deputy Undersecretary of Defense (Readiness).....1
   Attn: Lou Finch
   Room 3E774, The Pentagon
   Washington, D.C. 20310

8. Deputy Undersecretary of the Army for.....1
   Operations Research
   Attn: Walt Hollis
   Room 2E261, The Pentagon
   Washington, D.C. 20310

9. Commander.....1
U.S. Army TRADOC Analysis Command
Attn: Mr. Baumann
Fort Leavenworth, Kansas 66027-5200

10. Dynamics Research Corporation.....1
Attn: Dr. Michael Wagner
60 Concord Street
Wilmington, Massachusetts 01887-2193

11. Rolands and Associates Inc. 1
500 Sloat Avenue
Monterey, California 93940

12. Defense Manpower Data Center.....2
400 Giggling Road
Seaside, California 93955-6771

13. U.S. Army Concepts Analysis Agency.....1
Attn: Mr. E. B. Vandiver
8120 Woodmont Avenue
Bethesda, Maryland 20813-2797

14. Director, TRAC-Monterey.....1
Naval Postgraduate School
Monterey, California 93943-5002